Draft Principles & Guidelines for
Quantification of Policy Options & Scenarios

The purpose of this Quantification Memo is to propose and explain the principles, guidelines and general methods needed for quantifying socio economic impacts for recommended SB 375 and AB 32 policies and scenarios for the SCAG Region.

I. General Guidelines

Selection of Policy Options and Scenarios

The policies and scenarios that will be analyzed will be developed through the CEDP Process, including project timelines for tasks and sub tasks. In this process, three Technical Work Groups (TWGs) will cover key issue areas related to SB 375 and AB 32 in support of the Project Stakeholder Committee (PSC).

Through facilitative and technical support of the Center for Climate Strategies (CCS), and with advice and feedback from the Technical Advisory Panel (TAP) and Technical Review Committee (TRC), the PSC and TWGs will identify, design and guide analysis of the socioeconomic impacts analysis of specific policy options and aggregate scenarios (combined set or sets of policy options). Co-benefits will be described and or analyzed where possible and applicable.

The five issue based TWG areas include:
1. Transportation and Land Use (TLU) including development patterns and distribution of population, business/commercial and employment, housing
2. Transportation Infrastructure and Investments (TII) particularly transit investment and other infrastructure that may impact greenhouse gas (GHG) emissions
3. Transportation Demand Management (TDM) planning and programs
4. Transportation System Management (TSM) and operational policies and practices, and
5. Energy, Commerce and Resources (ECR), sector specific issues outside of the four transportation work groups, and multi-sector institutional and integrative issues incorporating: energy; agriculture, forestry and waste management; commercial, residential and industrial building sectors; industrial fuel use; and, cross cutting issues, including multi-sector institutional and integrative issues.

Specification of Policy Option Design Parameters

For each policy option and related scenario that is selected for design by the PSC and TWGs, a series of policy design parameters must be defined to support detailed quantification of impacts. These include:

- *Timing* (start and stop dates for the proposed)

- *Level of effort* (or goals for the proposed action)
- *Coverage of implementing or affected parties* (including geographic boundaries)
- *Other definitional issues* or eligibility provisions (such as renewable fuel definitions)

Specification of Policy Option Implementation Mechanisms

In addition, the instruments or mechanisms used to implement each policy option must be defined, at least in general terms, to capture potential variations in effectiveness. A variety of instruments or mechanisms exist, including:

- *Voluntary agreements*
- *Technical assistance*
- *Targeted financial assistance*
- *Taxes or fees*
- *Cap and trade*
- *Codes and standards*
- *Disclosure and reporting*
- *Information and education*
- *Others*

The impacts of each are policy specific and will vary by circumstance. For instance, price instruments, such as taxes and cap and trade, may perform better for policy options that are price responsive in comparison to those that are relatively unresponsive to price. Similarly, non-price instruments, such as codes and standards, may perform better where significant market barriers exist and require barrier removal.

Coverage and Metric of Policy Impacts

Quantitative estimates will be developed for the following types of impacts where applicable based on priorities set by SCAG and the PSC, and within the analytical capacity of the contract and process:

- *Net GHG reduction potential*, expressed as Million Metric Tons Carbon Dioxide Equivalent ($MMtCO_2e$) removed, including net effects of carbon sequestration or sinks, measured as an incremental change against a forecasted baseline; where very small denominations of GHGs are involved use of Metric Tons ($MtCO_2e$) may be used with notation.

- *Non GHG physical impacts* (such as on air quality or energy use), as appropriate and possible based on the availability of data, applied on a case-by-case basis

- *Individual or "stand alone" impacts* of policies, as well as *aggregate or interactive effects* of policy sets and scenarios ("system-wide" impacts); these will be measured as an incremental change against a forecasted baseline

- *Direct economic impacts*, also known as *net costs/savings*, *microeconomic analysis, or cost effectiveness* (expressed as $/$MMtCO_2e$ removed); this will include avoided costs of

policy options, such as avoided cost of investment in infrastructure or services from efficiency measures

- *Indirect or secondary economic impacts* on jobs, income, economic growth, and prices, also known as *macroeconomic impacts,* that arise from or in association with direct costs and savings

- *Distributional impacts,* including differential impacts related to size, location, and socio-economic character of affected households, entities, and communities; often framed as *fairness and equity*

- *Full life cycle impacts,* including net energy effects that include all inputs and outputs of projects, as possible based on the availability of data and relevance

- *Discounting* or time value of assets, typically using standard rates of 5 percent/yr real and 7 percent/yr nominal, applied to net flows of costs or savings over an appropriate time period corresponding to AB 32 and SB 375 targets and policy implementation horizons

- *Annualized impacts,* typically using levelization of net present value (NPV) impacts, that provide both cumulative and year-specific snapshots

- *Impacts beyond the end of the project period*; where additional GHG reductions or costs occur beyond the project period as a direct result of actions taken during the project period, these will be shown for illustration

Direct vs. Indirect Effects and Linkages

Socio-economic impacts of policy options and scenarios will include direct, indirect, and distributional effects. Direct effects are those borne or created by the specific entities, households or populations subject to the policy or implementing the new policies. Indirect effects are other than those specifically involved in implementing the policy recommendation. For instance, new vehicle standards may directly affect manufacturers and consumers of cars. Indirectly, their sales may increase or decrease local taxes and spending on goods and services that benefit from or are hurt by increased disposable income of the manufacturing workforce and consumers. These direct and indirect economic analyses are sequentially linked, with overlap. Direct effects must be calculated first in order for indirect effects and distributional impacts to be calculated.

Direct physical effects of GHG impacts will be estimated to support cost-effectiveness and GHG target evaluations. Indirect GHG effects will be conducted only as needed to address life cycle and boundary issues, based on availability of data, acceptability of methods, and priority. Examples of direct and indirect net costs and benefits metrics are included at the end of this memo for purposes of illustration.

Transparency of Analysis

All key elements of policy development and analysis will be explicitly provided for review and consideration by the PSC and TWGs, and all general methodological proposals will be available for TAP and TAC review. All proceedings and decisions of the process will be available for public review. This includes policy design and implementation mechanism choices (above) as well as the technical specification of analysis for options and scenarios. These technical specifications for analysis include:

- *Data sources*, based on best available data and PSC and TWG determinations

- *Methods and models,* following review and advice from the TAP and TAC, as well as PSC and TWGs

- *Key assumptions,* based on PSC and TWG determinations

- *Key uncertainties*, to be identified and discussed either qualitatively, or addressed through sensitivity analysis or other analytical approaches, as appropriate and possible.

Decisions on each of these variables will be made through open facilitated decisions of the PSC and TWGs, and CCS analysis will follow these guidelines and specifications as they are approved.

Documentation of Results

Documentation of the work completed for each policy option will be provided in a standard Policy Option Template format that addresses the following topics (among others) to ensure consistency for comparison of information and also assist with identifying data gaps that will be addressed.

- TWG Area (Sector)
- Name of policy option
- Plain English Policy Description
- Technical Policy Design Specifications
- Policy Implementation Mechanisms
- Related Policies and Programs in place or anticipated, for baseline definition
- Quantification Results, including:
  o Estimated Net GHG Savings in target years,
  o Cumulative GHG reduction potential and net costs/savings,
  o Net Cost/savings per cumulative $MMtCO_2e$ saved
  o Macroeconomic impacts,
  o Distributional impacts,
  o Specified data sources, quantification methods, and key assumptions
- Key Uncertainties and Sensitivity analyses
- Co-Benefits assessments or characterization, as appropriate
- Specific barriers to consensus, if any
- Final levels of PSC support

The completed Policy Option Templates will be assembled into a separate appendix of the final report. Additional printouts of worksheets and reference materials may be provided where needed.

II. Additional Background

Use of Pollutant Coverage and Global Warming Potentials

The analysis will cover the following six GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these gases will be presented using a common metric, CO_2e, which indicates

the relative contribution of each gas to global average radiative forcing on a Global Warming Potential- (GWP-) weighted basis. Table 1 shows the 100-year GWPs published by the Intergovernmental Panel on Climate Change (IPCC) in its Second, Third, and Fourth Assessment Report. To be consistent with the draft GHG emissions inventory and forecast for the state of California, the 100-year GWP's published in the IPCC's Second Assessment Report will be used to convert mass emissions to a 100-year GWP basis. Use of the 100-year GWP's published in the IPCC's Second Assessment Report is also consistent with U.S. Environmental Protection Agency (EPA) and IPCC guidance for consistency with how U.S. national, state, and country-specific GHG emissions inventories have been developed in the past.

Table 1. 100-Year Global Warming Potentials from the 2nd, 3rd, and 4th IPCC Assessment Reports

Gas	100-year GWP (2nd Assessment)[1]	100-year GWP (3rd Assessment)[2]	100-year GWP (4th Assessment)[3]
CO_2	1	1	1
CH_4	21	23	25
N_2O	310	296	298
HFC-23	11,700	12,000	14,800
HFC-125	2,800	3,400	3,500
HFC-134a	1,300	1,300	1,430
HFC-143a	3,800	4,300	4,470
HFC-152a	140	120	124
HFC-227ea	2,900	3,500	3,220
HFC-236fa	6,300	9,400	794
HFC-4310mee	1,300	1,500	1,640
CF_4	6,500	5,700	7,390
C_2F_6	9,200	11,900	12,200
C_4F_{10}	7,000	8,600	8,860
C_6F_{14}	7,400	9,000	9,300
SF_6	23,900	22,200	22,800

* The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor.

Emission Reductions

Emission reductions for individual policies will be estimated incremental to baseline emissions based on the change (reduction) in emissions activity (e.g., physical energy or activity units), or as a percentage reduction in emissions activity (e.g., physical energy or activity units or emissions) depending on the availability of data. This information will be needed to support the cost-effectiveness calculation for each policy option.

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[1] Second Assessment: http://www.epa.gov/climatechange/emissions/downloads/ghg_gwp.pdf 1995. Because only a summary of the Second Assessment Report if available online, an EPA document is cited which has the table from the IPCC report.
[2] Third Assessment: http://www.ipcc.ch/ipccreports/tar/wg1/248.htm, 2001.
[3] Fourth Assessment: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf, 2007.

Fuel- and pollutant-specific emission factors will be used to convert physical units of emissions activity to emissions. Activity based emissions factors may also be used where applicable. The emission factors will be based, initially, on those used by SCAG or ARB, or on other established and accepted protocols (such as those of the EPA or IPCC). For fuel combustion sources, fuel-specific oxidation factors will be used with emission factors to estimate emissions. Fuel combustion oxidation factors refer to the percentage of fuel that is fully oxidized during the combustion process. Table 2 provides the oxidation factors to be used for this analysis; these factors are based on those used in the EPA's most recent GHG inventory for the U.S.[4]

Table 2. Fuel Combustion Oxidation Factors

Fuel	Oxidation Factor
Coal	0.990
Natural Gas and LPG	0.995
Distillate and Residual Oil	0.990
Municipal Solid Waste	0.980

Net Costs and Savings

Net capital outlays and receipts, operation and maintenance (O&M) costs or savings, energy/fuel costs or savings, or other direct financial costs and savings will be estimated for each of the policies that are determined quantifiable. Costs and savings will be discounted as a multi-year stream of net costs/savings to arrive at the NPV cost associated with implementing new technologies and best practices. It is proposed that costs be discounted in constant 2005 dollars using a 5 percent annual real discount rate (7 percent nominal) based on standard rates used for regulatory impact analysis at the federal and state levels.

Capital investments will be represented in terms of annualized or amortized costs over the project period. Capital costs or savings represent the material, equipment, labor, and other costs or savings associated with the implementation of a policy option relative to the baseline or reference technology or practice. For policy options that require a capital investment, these costs will be annualized using a fixed charge rate (FCR), a factor that reflects the sum of the cost of capital (equals the cost of debt plus the cost of equity), taxes, and depreciation, as well as the lifetime of the investment.

O&M costs or savings refer to labor, equipment, and fuel costs related to annual operation and maintenance of policy measures, and are differentiated into annual expenditures (i.e., variable O&M) and fixed expenditures (i.e., fixed O&M). Variable O&M estimates are provided in activity units over the full period of operation of the technology. O&M costs are described and included in the life-cycle costs when there is a differential between the baseline technology and the GHG-reducing alternative.

Savings calculations include avoided costs of fixed and variable policy implementation investments, as applicable. For instance, location efficiency measures may reduce the required

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[4] U.S. EPA, April 2008. Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

infrastructure or services associated with new communities, depending on design and other circumstances. Similarly, electricity end use efficiency may reduce the need for new power generation facilities, and fuel efficiency measures may reduce the need for new fuel generation facilities.

Cost Effectiveness

Because the monetized dollar value of the impacts of GHG emissions reduction is not available, physical avoided emissions benefits are used instead as an input to cost effectiveness calculations, measured as dollars per $MMtCO_2e$ (cost or savings per ton), and referred to as "cost effectiveness". Both positive costs and cost savings (negative costs) are estimated as a part of the calculation of emissions mitigation costs. When combined with GHG impact assessments, the results of these cost estimates will be aggregated into a stepwise marginal cost curve that can be broken down by sector or subsector, as needed.

The net cost of saved carbon, or cost effectiveness, of a proposed policy is calculated by dividing the cumulative future streams of incremental costs or savings over the appropriate policy option time period, discounted back to the present time, by the cumulative undiscounted net CO_2e reductions achieved by the technology or best practice. Mathematically, the equation to be used is as follows:

$$ CSC \;=\; \frac{\displaystyle\sum_{t=0}^{n}\left\{ \frac{((LC_m - LC_r) * A_t)}{(1 + D_r)^t} \right\}}{\displaystyle\sum_{t=0}^{n}(CO_2e_r - CO_2e_m)} $$

Where:

CSC = Cost of saved carbon (or cost-effectiveness) of a technology or best practice, $/MtCO_2e$ avoided

LCm = Levelized cost of a technology or best practice, $/activity unit

LCr = Levelized cost of the baseline or reference technology or best practice, $/activity unit

A = Amount of activity affected by the technology or best practice in year t, activity unit

Dr = Real discount rate, dimensionless

CO_2er = CO_2e emissions associated with the baseline or reference technology in year t, tons CO_2e

CO_2em = CO_2e emissions associated with a technology or best practice in year t, tons CO_2e

t = year in the evaluation period ($0 \le t \le 40$)

Activity units refer to a unit indicator of GHG emissions activity for a policy option. The activity units will vary depending on the Area (sector) and within each sector by the individual option. The activity units are used to normalize data for comparison of the policy option to the baseline. For example, for the Power Supply sector, megawatt-hours (MWh) of gross electricity generation could be used as the activity unit such that dollars per megawatt-hour ($/MWh) would be used as the activity unit for the "LCm" and "LCr" terms and MWh would be used as the activity unit for the cost terms in the equation.

The results of the analyses will be used to develop a GHG abatement cost curve, which will rank each technology or best practice in the order of its cost effectiveness for reducing a MtCO₂e of emissions. This ranking will be represented in the form of a curve. Each point on this curve represents the cost-effectiveness of a given policy option relative to its contribution to reductions from the baseline, expressed as a percentage of baseline emissions. The points on the curve appear sequentially, from most cost-effective in the lower left area of the curve, to the least cost-effective options located higher in the cost curve in the upper right area.

Levelized Costs

The costs of each policy option that will be evaluated will be levelized and converted into dollars per activity unit. The cost components to be considered include capital, fixed O&M, variable O&M, and fuel costs and savings. Other sector-specific direct costs and savings (e.g., savings from avoided losses in transmission of electricity) will be included as applicable to each sector or policy option (see CCS example provided for power generation).

The levelization calculation is similar to amortization and its purpose is to develop a level stream of equal dollar payments that lasts for a fixed period of time. This allows snapshot evaluations of policy impact at any given point in time in a manner that incorporates the fixed and variable expenses and savings over the full time period applicable to implementation of the policy. The levelization formula to be used in the analysis is as follows:

$$LC = \frac{[PV * D_r * (1 + D_r)^t]}{((1 + D_r)^t) - 1}$$

Where:

LC	=	Levelized cost of the a technology or best practice, $/activity unit
PV	=	Present value of discounted cost stream
D_r	=	Real discount rate, dimensionless
t	=	Levelization period, or number of years over which payments are to be made

There are several parameters that will be used in the levelization process for different policy costs. Some are technology-specific (e.g., plant lifetime, capacity factor), others are region-specific (e.g., state or local income tax rate), others are market-driven (cost of capital or energy), while others are driven by policy (e.g., real discount rate). Attachment 1 to this memo provides an example of how levelized costs are calculated.

Time Period of Analysis

For each policy option, incremental emission reductions and incremental costs and savings will be calculated relative to the characteristics of the baseline that would otherwise prevail in the SCAG region up through the end of the planning period that corresponds to AB 32 and SB 375 target years, as well as the lifetime of the policy option in question. The NPV of the cumulative net costs of each option, and the cumulative emission reductions of each option, will be reported for the AB 32 and SB 375 period starting with the initial year of the phase-in of the policy up through the target period for analysis. For example, if a policy includes a complete phase-in over time, the annual GHG reductions and the NPV of the incremental costs and the cumulative emission reductions will be reported for the entire period from the beginning of the phase-in up through the end of the target years for analysis.

Geographic Inclusion

GHG impacts of activities that occur within the SCAG region will be estimated, regardless of the actual location of emissions reductions. For instance, a major benefit of recycling is the reduction in material extraction and processing (e.g., bauxite mining and aluminum production) and in energy use for same. While a policy option may increase recycling in the region, the reduction in emissions may occur where the recycled materials are produced. Where significant emissions impacts are likely to occur outside the SCAG region, this will be clearly indicated. These emissions reductions are counted towards the achievement of the region's emission goal, since they result from actions taken by the region.

Fuel and Life Cycle Coverage

GHG reductions for each policy option will be based on a life cycle and net energy impact analysis wherever possible, based on best available data and priority need. Tracking the full range of fuel use inputs is preferred, and in some cases essential, for accurately tracking full cycle carbon emissions for technology options and best practices displaying very different performance characteristics from the standard practices they are replacing. The approach involves identifying all the possible stages of the fuel cycle, for instance, and quantifying the fuel input per unit of energy produced (electricity or fossil fuel). The focus, however, will be on those fuel cycle elements where there are significant differences in greenhouse gas emissions between the business or reference case (standard practice) and the policy option.

Life cycle impacts will be reported for each source for which information is available to support a life cycle analysis. Where life cycle emission reductions are captured, there can often be two sets of emission reductions estimated: the total life cycle reductions and those estimated on a direct basis. In most cases, these will likely be difficult to separate based on available information. Therefore, by default, the in-region reductions will often be those associated with estimated differences in fuel combustion between standard practice and policy cases for in-region processes.

Emission reductions from in-region processes associated with non-combustion reduction sources include only those processes that are known to occur within the SCAG region (e.g., landfill emission reductions, but not the upstream GHG emissions embedded in the waste component) and exclude processes where the geographic origin of the mitigated emissions is uncertain (e.g., emissions from extraction/processing/packaging of virgin materials into usable products).

Macroeconomic Impacts

The principles and guidelines and key decisions on methods, data sources and assumptions for macroeconomic analysis will be provided in a separate and linked advisory memo.

Distributional Impacts

The principles and guidelines and key decisions on methods, data sources and assumptions for distributional impact analysis, including environmental justice and small business impacts, will be provided in a separate and linked advisory memo.

Co-benefits Assessments

To the extent needed, the principles and guidelines and key decisions on methods, data sources and assumptions for co-benefits analysis will be provided in a separate and linked advisory memo by CCS.

* For additional reference see the economic analysis guidelines developed by the Science Advisory Board of the US EPA available at:
http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html.

Examples of Direct/Indirect Net Cost and Benefit Metrics

Note: These examples are meant to be illustrative and are not necessarily comprehensive or the focus of the CEDP Climate Planning Process.

1. **Transportation and Land Use (TLU) Sector**

    a. Direct Costs and/or Savings

        i.   Incremental capital and operating cost of more efficient vehicles, net of fuel savings.

        ii. Incremental costs of implementing Smart Growth programs, net of saved infrastructure and service costs.

        iii. Incremental cost of mass transit investment and operating expenses, net of any saved infrastructure and service costs (e.g., roads, road maintenance, vehicles)

        iv. Incremental cost of alternative fuel, net of any change in maintenance costs

        v.   Net effects of carbon sequestration from land use measures

    b. Indirect Costs and/or Savings

        i.   Net value of employment and income impacts, including differential impacts by socio economic category

        ii. Re-spending effects on the economy from financial savings

        iii. Net changes in the prices of goods and services in the region

        iv. Health benefits of reduced air and water pollution

        v.   Ecosystem benefits of reduced air and water pollution

        vi. Value of quality-of-life improvements

        vii. Value of improved road and community safety

        viii. Energy security

2. **Residential, Commercial, and Industrial (RCI) Sectors**

    a. Direct Costs and/or Savings

        i.   Net capital costs or savings (or incremental costs or savings relative to standard practice) of improved buildings, appliances, equipment (for example, cost of higher-efficiency refrigerator versus refrigerator of similar size and with similar features that meets standards)

        ii. Net operation and maintenance (O&M) costs or savings (relative to standard practice) of improved buildings, appliances, equipment, including avoided/extra labor costs for maintenance (for example, maintenance cost savings from less changing of longer-lived compact fluorescent light

(CFL) or light-emitting diode (LED) bulbs in lamps relative to incandescent bulbs)

    iii. Net fuel (gas, electricity, biomass, etc.) costs (typically expressed as avoided costs from a societal perspective, that is, based on the net cost to society of producing an additional unit of fuel, as opposed to the retail cost of fuel)

    iv. Cost/value of net water use/savings

    v. Cost/value of net materials use/savings (for example, raw materials savings via recycling, or lower/higher cost of low-global warming potential (GWP) refrigerants)

    vi. Direct improved productivity as a result of industrial measures (measured as change in cost per unit output, for example, for an energy/GHG-saving improvement that also speeds up a production line or results in higher product yield)

  b. Indirect Costs and/or Savings

    i. Net value of employment and income impacts, including differential impacts by socio economic category

    ii. Re-spending effect on economy

    iii. Net value of health benefits/impacts

    iv. Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

    v. Net embodied energy of materials used in buildings, appliances, equipment, relative to standard practice

    vi. Improved productivity as a result of an improved working environment, such as improved office productivity through improved lighting (though the inclusion of this as indirect might be argued in some cases)

3. Energy Supply (ES) Sector

  a. Direct Costs and/or Savings

    i. Net capital costs or savings (or incremental costs or savings relative to reference case technologies) of renewables or other advanced technologies implemented as a result of policies

    ii. Net O&M costs or savings (relative to reference case technologies) of renewables or other advanced technologies implemented as a result of policies

    iii. Avoided or net fuel savings (gas, coal, biomass, etc.) of renewables or other advanced technologies implemented as a result of policies relative to reference case technologies

    iv. Total system costs (net capital + net O&M + avoided/net fuel savings + net imports/exports + net transmission and distribution (T&D) costs) relative to reference case total system costs

  b. Indirect Costs and/or Savings

    i. Net value of employment and income impacts, including differential impacts by socio economic category

    ii. Re-spending effect on economy

    iii. Higher cost of electricity in the region

    iv. Energy security

    v. Net value of health benefits/impacts

    vi. Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

4. Agriculture, Forestry, and Waste Management (AFW) Sectors

  a. Direct Costs and/or Savings

    i. Net capital costs or savings (or incremental costs relative to standard practice) of facilities or equipment (e.g., manure digesters, biogas-fired generators, and associated infrastructure; ethanol production facilities)

    ii. Net O&M costs or savings (relative to standard practice) of equipment or facilities

    iii. Net fuel (gas, electricity, biomass, etc.) costs or avoided costs

    iv. Cost/value of net water use/savings

    v. Cost/value of carbon sequestration from land use measures

    vi. Reduced vehicle miles traveled (VMT) and fuel consumption associated with land use conversions (e.g., as a result of forest/rangeland/cropland protection policies)

  b. Indirect Costs and/or Savings

    i. Net value of employment and income impacts, including differential impacts by socio economic category

    ii. Net value of human health benefits/impacts

    iii. Net value of ecosystem health benefits/impacts (wildlife habitat; reduction in wildfire potential; etc.)

    iv. Value of net environmental benefits/impacts (value of damage by air or water pollutants on structures, crops, etc.)

    v. Net embodied energy of water use in equipment or facilities relative to standard practice

Attachment I

Example Calculation of Levelized Costs

This memo provides a brief conceptual overview as well as an annotated example regarding the calculation of levelized costs associated with power generation technology. Levelized costs are useful in evaluating financial feasibility and for directly comparing the cost of one technology against another.

Conceptual Overview of Levelized Costs

Levelized cost can be defined as a constant annual cost that is equivalent on a present value basis to the actual annual costs. That is, if one calculates the present value of levelized costs over a certain period, its value would be equal to the present value of the actual costs of the same period. Using levelized costs, often reported in $/MWh, allows for a ready comparison of technologies in any year, something that would be more difficult to do with differing annual costs. This can be illustrated in the Figure below. The present value of the levelized cost as shown is exactly equal to the present value of the annual costs.

Figure 1: Illustrative comparison of levelized and actual annual costs
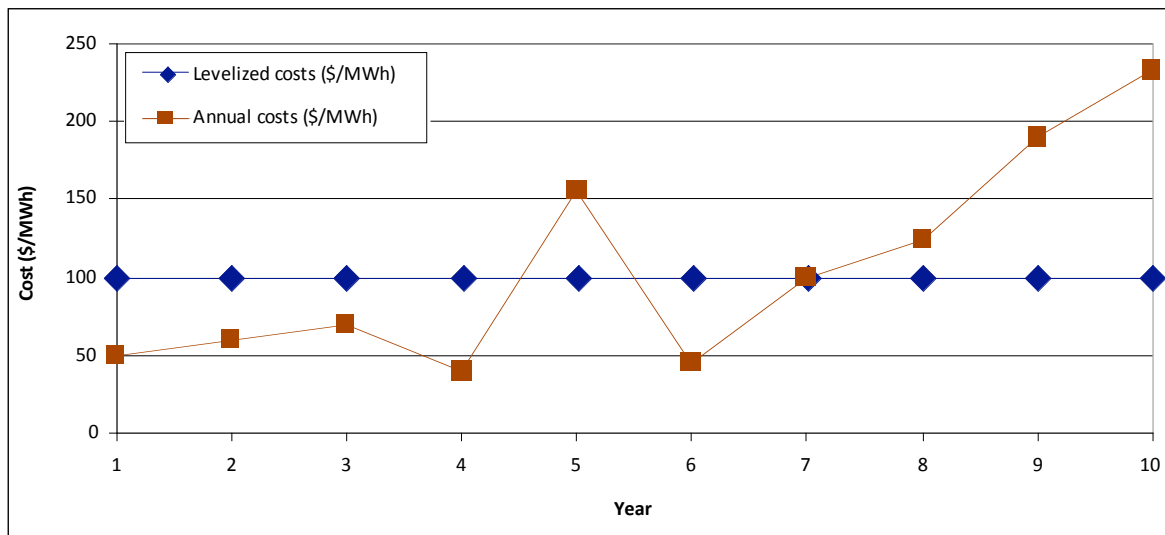
$/MWh = cost per megawatt hour

Components of Levelized Costs

For power generation technologies, there are several components that typically make up the levelized cost, as briefly described in the bullets below.

- *Capital costs:* Typically reported in units of $/kW, these costs include the total costs of construction, including land purchase, land development, permitting, interconnections, equipment, materials and all other components. Construction financing costs are also included.

- *Fixed operations & maintenance (O&M):* Typically reported in units of $/kW-yr, these costs are for those that occur on an annual basis regardless of how much the

plant operates. They typically include staffing, overhead, regulatory filings, and miscellaneous direct costs.

- *Variable O&M:* Typically reported in units of $/MWh, these costs are for those that occur on an annual basis based on how much the plant operates. They typically include costs associated with maintenance and overhauls, including repairs for forced outages, consumables such as chemicals for pollution control equipment or boiler maintenance, water use, and other environmental compliance costs.

- *Fuel:* Typically reported in units of dollars per million British Thermal Units of fuel heat content ($/mmbtu), these costs are for startup fuel use as well as online fuel use.

Information needed to Calculate Levelized Costs

There are several other bits of information that is needed in order to calculate levelized costs, as briefly described in the bullets below.

- *Plant size:* This refers to the size of the plant, expressed in units of MW.
  - *Capacity factor:* This refers to the share of the year that the plant is in operation, expressed as a percentage.

  - *Fixed charge factor:* This factor is calculated based on assumptions regarding the plant lifetime, the effective interest rate or discount rate used to amortize capital costs, and various other factors specific to the power industry. Expressed as a decimal, typical fixed charge factors are typically between 0.10 and 0.20, meaning that the annual cost of ownership of a power generation technology is typically between 10 and 20 percent of the capital cost. Fixed charge factors decrease with longer plant lifetimes, and increase with higher discount or interest rates.

  - *Fuel price projection:* This refers to the projected price of the fuel used to produce electricity over the lifetime of the plant, expressed in units of $/mmbtu in each year of the fuel price forecast. Price projections from the U.S. Department of Energy's Energy Information Administration are often used. In some cases, fuel price projections are expressed as levelized values for use in calculating the overall levelized costs of generation.

  - *Heat rate:* This refers to the efficiency by which fuel is consumed for the production of electricity, expressed in units of btu/kWh.

Formulas used to Calculate Levelized Costs

There are several formulas needed to convert the various units into the $/MWh units used to express levelized costs. These are briefly described below.

- *Capital costs (CC):* These costs are converted to $/MWh units as per the formula below:

  *Levelized capital cost = CC * FCF * conversion factor / (HPY * CF)*

  Where: CC = capital cost ($/kW)
  CF = capacity factor (%)
  HPY = hours per year = 8,760
  FCF = fixed charge factor
  conversion factor = 1,000 (convert from $/kW to $/MW)

- *Fixed O&M (FOM):* These costs are converted to $/MWh units as per the formula below:

Levelized fixed O&M cost = FOM * conversion factor / (HPY * CF)

Where: FOM = fixed O&M ($/kW-yr)
          CF = capacity factor (%)
          HPY = hours per year = 8,760
          conversion factor = 1,000 (convert from $/kW to $/MW)

- *Variable O&M (VOM):* These costs are already provided in units of $/MWh so no conversion is needed.

- *Fuel costs (FC):* Each year's fuel price is converted to units of $/MWh as follows:
          Fuel price = FP_t * HR / conversion factor

Where: FP_t = fuel price in year t ($/mmbtu)
          HR = heat rate (btu/kWh)
          Conversion factor = 1,000 (convert from kWh to MWh)
          t = year in the plant lifetime

These annual fuel costs are then levelized as follows:
          Levelized fuel cost = [PV * DR * $(1+DR)^t$] / [$(1 + DR)^t$ – 1]

Where: PV = present value of discounted fuel cost stream
          DR = discount rate

Example Calculation of Levelized Costs

The above information can be combined to develop the levelized cost for any technology. As an example, the case of a conventional natural gas-fired combined cycle plant is considered. Table 1 summarizes the starting assumptions. Levelized cost calculations are offered in the bullets that follow the table. Note that cost parameters are specified on a per-unit basis, the calculation is independent of the size of the generator.

Table 1: Cost and Performance Assumptions

Parameter	Value	Annual Fuel Price (constant $/mmbtu)					
		Year	Price	Year	Price	Year	Price
Size (MW)	540	1	7.57	11	6.09	21	6.57
Online year	2012	2	7.12	12	6.14	22	6.61
Fuel type	Natural gas	3	7.54	13	6.20	23	6.83
Heat rate (btu/kWh)	7,064	4	7.77	14	6.25	24	6.96
Capacity factor (%)	65%	5	7.30	15	6.16	25	7.09
Discount rate (%)	5.0%	6	7.01	16	6.06	26	7.20
Operating life (years)	30	7	6.77	17	6.18	27	7.25
Fixed charge factor (%)	12%	8	6.47	18	6.25	28	7.30
Capital cost ($/kW)	703	9	6.26	19	6.36	29	7.35
Fixed O&M cost ($/kW-yr)	12.14	10	6.14	20	6.46	30	7.4
Variable O&M cost ($/MWh)	2.01						

$/mmbtu = cost per million British thermal units; MW = megawatt; btu/kWh = British thermal units per kilowatt hour; $/kW = cost per kilowatt; O&M = operation and maintenance;

- *Capital costs:* The levelized capital cost is equal to:
          Levelized capital cost = 703 * 0.12 * 1,000 / (8,760 *0.65) = $14.82/MWh

- *Fixed O&M:* The levelized fixed O&M cost is equal to:
  Levelized fixed O&M cost = 12.14 * 1,000 / (8,760 * 0.65) = $2.13/MWh

- *Variable O&M:* The levelized variable O&M cost is equal to $2.01/MWh

- *Fuel costs:* The present value of the discounted fuel cost stream is equal to $104.35/mmbtu. The levelized fuel cost is equal to:
  $$[\ 104.35 * 0.05 * (1+0.05)^{30}\ ] / [\ (1 + 0.05)^{30} - 1\ ] = \$6.79/mmbtu$$

  This levelized value is then converted to units of $/MWh as follows:
  Levelized fuel cost = 6.79 * 7,064 / 1,000 = $47.97/MWh

- *Total levelized cost:* The total levelized cost is equal to the sum of the above components, as follows:
  Total levelized cost = levelized CC + levelized FOM + VOM + levelized FC
  = 14.82 + 2.13 + 2.01 + 47.97
  = $66.93/MWh